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ABSTRACT

Spatial visualization is not yet clearly understood. Some researchers have concluded that two factors or abilities are involved, spatial orientation and spatial visualization. Different definitions and different tests have been proposed for these two abilities. Several studies indicate that women generally perform more poorly on spatial tests than do men; it has been suggested that this sex difference has an hereditary basis. Several studies support this hypothesis. A study has shown that females with Turner's Syndrome perform much more poorly on Wechsler performance subtests than on the verbal subtests, but immaturity due to parental indulgence may account for these results. A research question of considerable interest is at how early an age spatial ability can be tested. Few attempts have been made to improve performance on spatial tests by practice or relevant training, but the author has such a study with third and fifth graders underway. Such studies have shown training to improve scores considerably. References are provided. (KM)

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HEREDITARY FACTORS IN SPATIAL VISUALIZATION

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Ever since the subtest "Block Counting" was included in the Army Beta Test and Thorndike (1921) showed that performance on it did not correlate highly with "general intelligence", there has been an interest in what came to be called "spatial" tests. The history of these tests has been described by McFarlane Smith (1964).

In the United Kingdom such tests are usually described as measures of a factor 'k' variously named "practical", "concrete" or "spatial" since El Koussy's study of the visual perception of space (1920).

The precise nature and limits of the hypothesized ability is not clearly understood, in part, because some authors have used the term "spatial" to describe features of tests which merely use geometric figures, but do not require visualization of two or three dimensional objects. Examples of such tests which sometimes have been called spatial are the Progressive Matrices of Raven (1952) various form boards, mazes and the Kohs blocks. Actually, the latter may have a "spatial" component in it because it requires two dimensional rotation. However, to the extent that the designs can be copied by trial and error, this test would require mainly verbal reasoning and form perception.

There may be several distinguishable abilities. French (1951) reviewed several factor analytic studies and concluded that two factors existed which could be described as spatial orientation and spatial visualization. Spatial orientation he defined as the aptitude to remain unconfused by changing orientations in which a spatial configuration may be presented and spatial visualization as the aptitude to comprehend imaginary movement in three dimensional space.

Guilford and his associates also proposed two factors with the same names but with slightly different definitions. Spatial orientation they see as an ability to appreciate spatial relations with reference to the body of the

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PS 006479

observer and spatial visualization as a process of imagining movements, transformations and other changes in visual objects. (Michael et al., 1951, 1957 - Guilford & Zimmerman, 1956).

Although the names of the two abilities are identical, French and Guilford proposed different definitions and different tests to measure these abilities. French (1962) selected a test of Thurstone's "Identical Blocks" to measure spatial orientation. In this test subjects are required to decide whether two cubes in different orientations are identical or not according to symbols shown on the faces of the cubes. For visualization he selected another of Thurstone's tests called "Paper Folding". Here the subject is asked to imagine folding and unfolding a piece of paper and deciding where holes punched in the folded paper will show in the unfolded paper.

Guilford and Zimmerman (1956) constructed for spatial orientation a test in which the subject is asked to select one picture out of 5 of a boat in which he is supposedly riding, judging from a drawing showing the prow of the boat in relation to the horizon.

For spatial visualization they constructed a test in which the subject has to visualize rotating an alarm clock to decide which of 5 pictures shows its orientation after it has been moved as shown by an arrow.

Borich & Bauman (1972) found the correlations shown in Table 2 between these 4 tests, when they applied the Campbell and Fiske (1959) multitrait-multi method model to test scores of 40 college students.

		Guilford-Zimmerman Spatial		French Spatial	
		Orientation	Visualization	Orientation	Visualization
GZ	S.O.	(.88) ^x			
	S.V.	.67	(.93) ^x		
Fr.	S.O.	.48	.53	(.66) ^x	
	S.V.	.34	.44	.55	(.51) ^x

^xReliability reported by test authors.

Although the sample size was rather small, their results indicate that the two abilities measured by tests of the same author correlate higher than do tests of the same ability constructed by different authors.

A large variety of tests have been constructed which aim at measuring these and closely related abilities. In the appendix a list of such tests and sample items are included.

Performance on spatial tests is less correlated with social class differences than is performance on vocabulary tests or on tests of general intelligence. (Nuttin, 1965 - Cliquet, 1963).

On the other hand there are several reports that women generally do poorer on such tests than do men (Maccoby, 1966).

In 1943 O'Connor suggested that this sex difference has an hereditary basis. Support for this hypothesis has come from several sources:

1. R.E.Stafford (1963) obtained a pattern of father-son, father-daughter, mother-son and mother-daughter correlations suggestive of sex linkage. Similar results have been reported by Hartlage (1970) and Bock & Kolakowski (1973). The latter analyzed the results from the previous two studies and their own and concluded that the results are consistent with the hypothesis that spatial ability depends on a recessive gene on the x-chromosome with a frequency of approximately

.5 in U.S. whites.

2. The results of several twin studies indicate that spatial ability has a considerable genetic component in each of the samples studied. (Vandenberg, 1969).

3. The genetic component in spatial test scores seems to be largely independent from the genetic component in other ability test scores. (Vandenberg 1965, Bock & Vandenberg, 1968).

Money and his associates reported that phenotypic females with XO aneuploidies, the so-called Turner syndrome, did much poorer on the non-verbal or "performance" subtests of the Wechsler than on the verbal subtests. He suggested that this was due to a specific impairment of mental functioning which he labelled visual agnosia. He related it to the earlier reports of a sex-difference in spatial ability and proposed that it is this ability which is impaired in Turner's Syndrome.

Money constructed a special road map test of directions thought to measure this ability.

However, more recently Money (1970) has reported that persons with Turner's syndrome have certain personality characteristics which are, at least in part, due to the fact that they are usually "infantilized" by their parents i.e., they are given less than the normal amount of responsibility and are treated as if they were younger than they really are.

This factor may contribute to their poorer performance on non-verbal than on verbal tests.

Such a psychological explanation which makes the effects not a direct genetic one but one secondary to the delayed physical development is reminiscent of recent proposals that the increased incidence of XYY in violent criminals is due to their increased height and earlier growth which may lead to more fighting during adolescence.

A question which is of considerable theoretical and applied interest is at how early an age spatial ability can be tested. To my knowledge no such data is available on the paper and pencil tests of Guilford or French, but studies of Piaget and others on spatial concepts may be relevant as well as perhaps studies with certain "performance" tests such as mazes or Kohs' Blocks.

Recently I have administered a test constructed from the Metzger-Shepard figures to 5th graders. It is now being administered to 3rd graders. They will be retested after having had an opportunity to build from blocks some of the models shown in this test, to see what the effect will be of systematic efforts to construct such models.

There have been few other attempts to improve the performance on spatial tests by practice or relevant training. Brinkmann (1966) compared the performance of two groups of 8th grade students on the DAT spatial relations test. Both groups were tested twice, but only one group received a self instructional program intended to increase understanding of selected concepts in geometry. This group scored very much higher ($p < .001$) than the control group: the mean for the experimental group increased by 18 points while the mean for the control group increased only 3 points. The author contrasts his findings with the negative results from three unpublished studies of the effect of regular course in geometry or mechanical drawing on spatial ability test scores.

In an earlier study, Blade & Watson (1955) found significant increases in spatial test scores after a year of engineering courses. Students in other curricula obtained much smaller gains. Incidentally, they also reported that performance in the upper third on the spatial test was as good a predictor of success in engineering school as scoring in the upper third of a mathematics test.

PS 006-129

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